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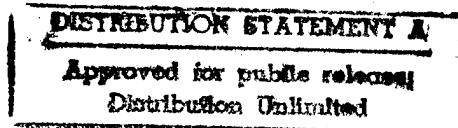
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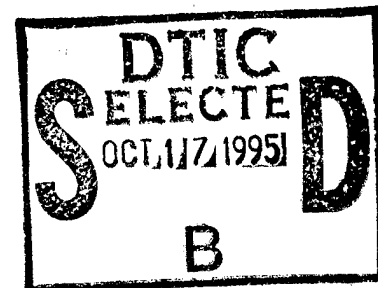


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PIC Simulation of Surface Waves

AASERT Annual Progress Report  
9/1/94 - 8/31/95

Charles K. Birdsall, Principal Investigator  
David Cooperberg, Graduate Student Researcher

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## Annual Report

AASERT Award for Proposal

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### PIC Simulation of Surface Waves

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This is a description of work David Cooperberg has done as a graduate student in the last year supported by an ONR AASERT in Professor C. K. Birdsall's Plasma Theory and Simulation Group.

Surface waves are being investigated via electrostatic particle simulation of a warm, unmagnetized, bounded  $2\frac{1}{2}d$  plasma. Our study focuses on a slab configuration in which the plasma is periodic in the  $y$  direction and is bound in the  $x$  direction by grounded, absorbing, conducting walls. Our prior simulation has produced dispersion relations and eigenfunctions for surface waves analogous to the Gould-Trivelpiece[1] waves in cylindrical systems for which the  $k_y = 0$  cut-off of the asymmetric mode defines the series resonance and secondary branches[2] whose cutoffs represent Tonks-Dattner resonances[3][4]. The current work involves studying 2 species, low voltage, collisional systems sustained both by uniform ionization, for which the randomly excited surface wave modes remain in a linear regime, and also by resonant interaction with surface waves which are excited beyond the linear regime by applied voltages of order  $kT_e$ . This investigation is important for both basic sheath understanding and for applications such as large area plasma processing, new light sources, lasers, and ion sources. Electromagnetic simulations are also being initiated to verify our results.

In order to further our study of surface waves as a mechanism for sustaining plasma discharges, work has been performed in modifying the Monte Carlo collision code written by Vahid Vahedi. Enhancements have been made by allowing simulation particles to have their own variable weights. The reasoning for this work is as follows.

In order to use particle-in-cell (PIC) simulation codes for modeling collisional plasmas, such as self-sustained discharges, it is necessary to add interactions between charged and neutral particles. A Monte-Carlo collision (MCC) package for particles of various weights has been developed and is being tested. This scheme can in general reduce the number of computer particles needed to represent selected species which allows

for a significant reduction in simulation size at runtime, as in the case of highly electronegative discharges where the ion densities may be far greater than the electron density. Also, by choosing a constant number of computer particles to be used through the duration of the run, a consistent level of numerical fluctuation may be maintained. We have tested this scheme to simulate  $O_2$  discharges at low powers and high pressures and have made some analysis of regimes in which anomalous heating might degrade the performance of the variable weight approach.

## References

- [1] A. W. Trivelpiece and R. W. Gould, J. Appl. Phys. **30**, 1784 (1959)
- [2] B. O'Brien, R. W. Gould and J. Parker, Phys. Rev. Letters **14**, 630, (1965)
- [3] D. J. Cooperberg and C. K. Birdsall, Bull. APS II, **39**, 7, 1552 (1994)
- [4] J. V. Parker, J. C. Nickel and R. W. Gould, Phys. Fluids **7**, 1489 (1964)

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